Foto: Försvarsmakten/David Gernes

Implementing a method for age determination of uranium using the $^{230}Th/^{234}U$ chronometer

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Background

Nuclear forensics:

- What? Where from? Why?

- Comparative signatures
- Origin assessment

- Age determination
  - Predictive signature

Chronometers

- $^{230}Th/^{234}U$
- $^{231}Pa/^{235}U$
- $^{214}Bi/^{234}U$

- Assumptions
  - Closed system
  - No Th at t_0

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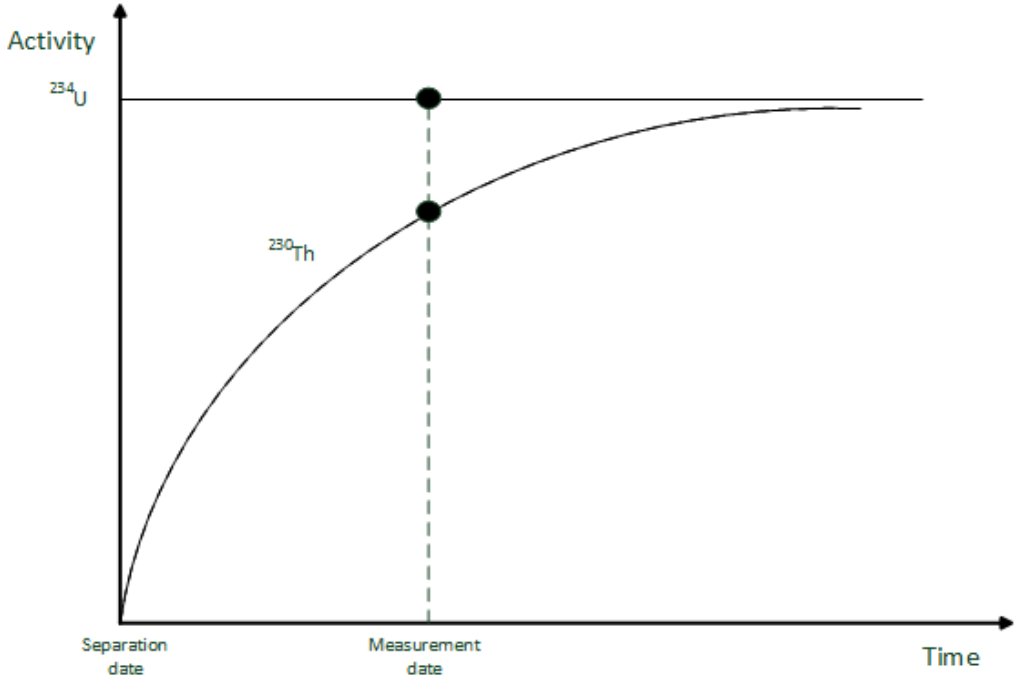
Ingrowth and age

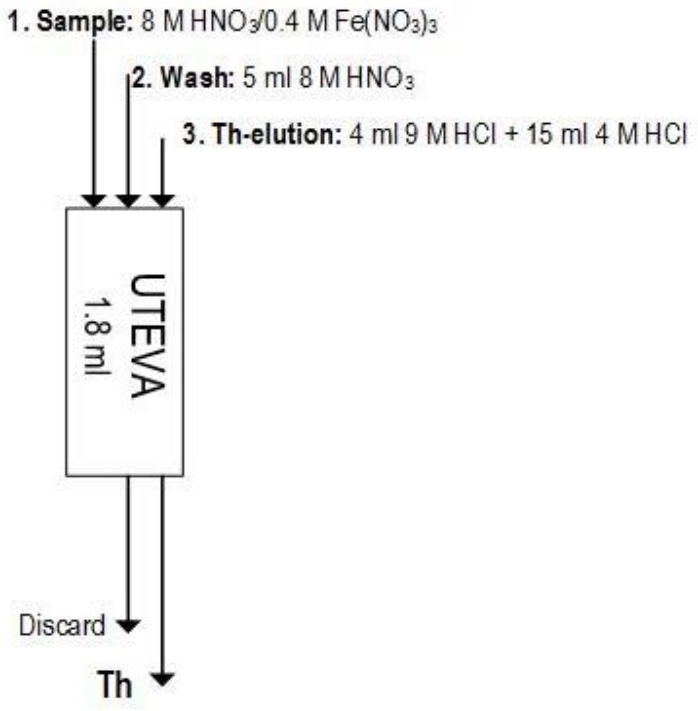


$$N_{Th}(t) = N_{0Th}e^{-\lambda_{Th}t} - \lambda_U N_{0U}\left(\frac{e^{-\lambda_{Th}t} - e^{-\lambda_U t}}{\lambda_{Th} - \lambda_U}\right) \quad \rightarrow\rightarrow \quad t = \frac{1}{\lambda_U - \lambda_{Th}} \cdot ln\left(1 - \frac{N_{refTh}}{N_{refU}}\left(\frac{\lambda_{Th}}{\lambda_U} - 1\right)\right)$$

Outline of the method

1. Pre-analysis
2. Th separation
3. Measurement of ^{230}Th and ^{234}U
4. Calculations

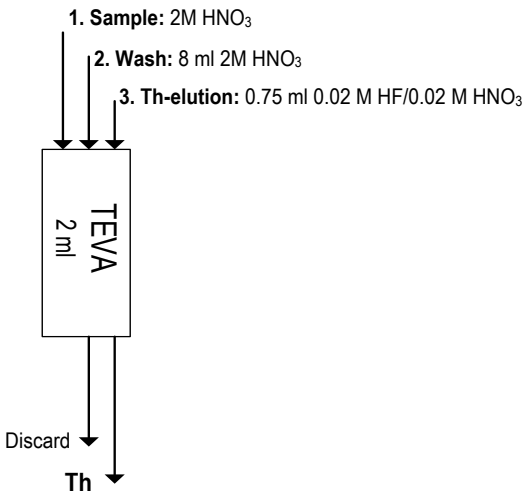
^{229}Th tracer preparation



- No reference material certified for ^{229}Th mass

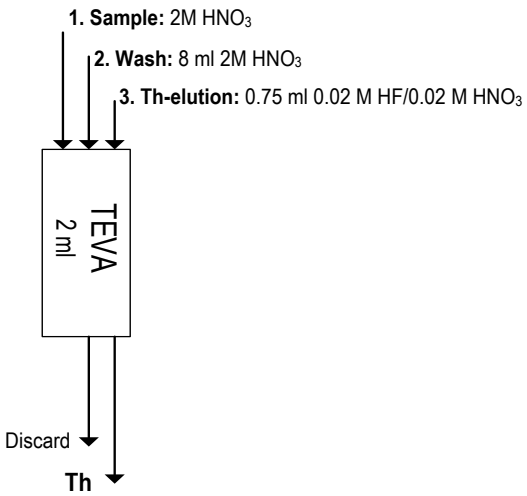
  ➡ In-house tracer
- Base material: IRMM-040a
- ^{229}Th concentration determined by reverse isotope dilution with IRMM-060

Thorium separation



- Based on Varga et al.
  - Varga Z., Surányi G., *Production date determination of uranium-oxide materials by inductively coupled plasma mass spectrometry*, Anal. Chim. Acta, 599 (2007) 16-23
  - Varga Z., Wallenius M., Mayer K., Hrnecek E., *Alternative method for the production date determination of impure uranium ore concentrate samples*, J. Radioanal. Nucl. Chem., 290 (2011) 485-492

Thorium separation



- Evaporation and dissolution in 2 M HNO3
- Separation repeated once

Measurement

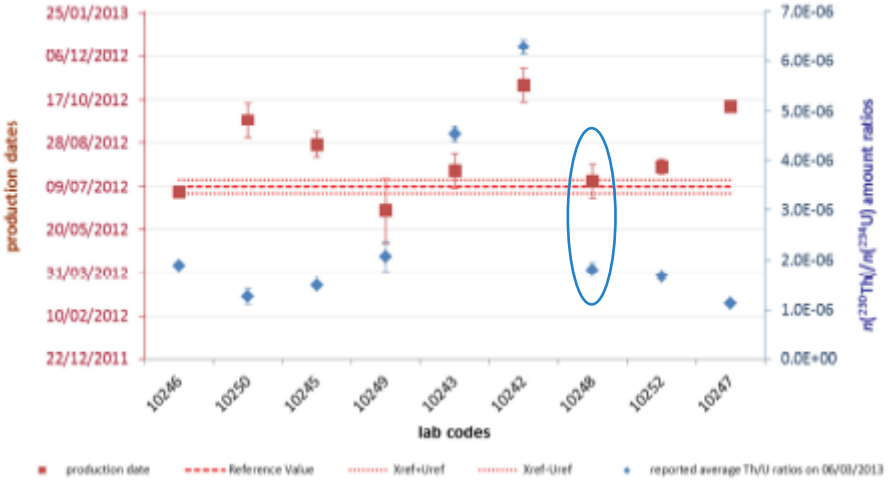
- Element XR with Twinnabar spray chamber and Micromist nebulizer
- IRMM-073/1 used for mass bias correction
- All calculations, including dead time correction done post-acquisition

Participation in REIMEP-22

- 20 mg uranyl nitrate
- Approx. 4% enrichment

- Reported date: 2012-07-15 ± 19 d
- Reference date: 2012-07-09 ± 7.8 d

- Reference material: IRMM-1000



Ref: Venchiarutti C. et al., *REIMEP-22 U Age Dating – Determination of the production date of a uranium certified test sample: Inter-laboratory comparison, Report to participants*, ISSN 1831-9424, 2015

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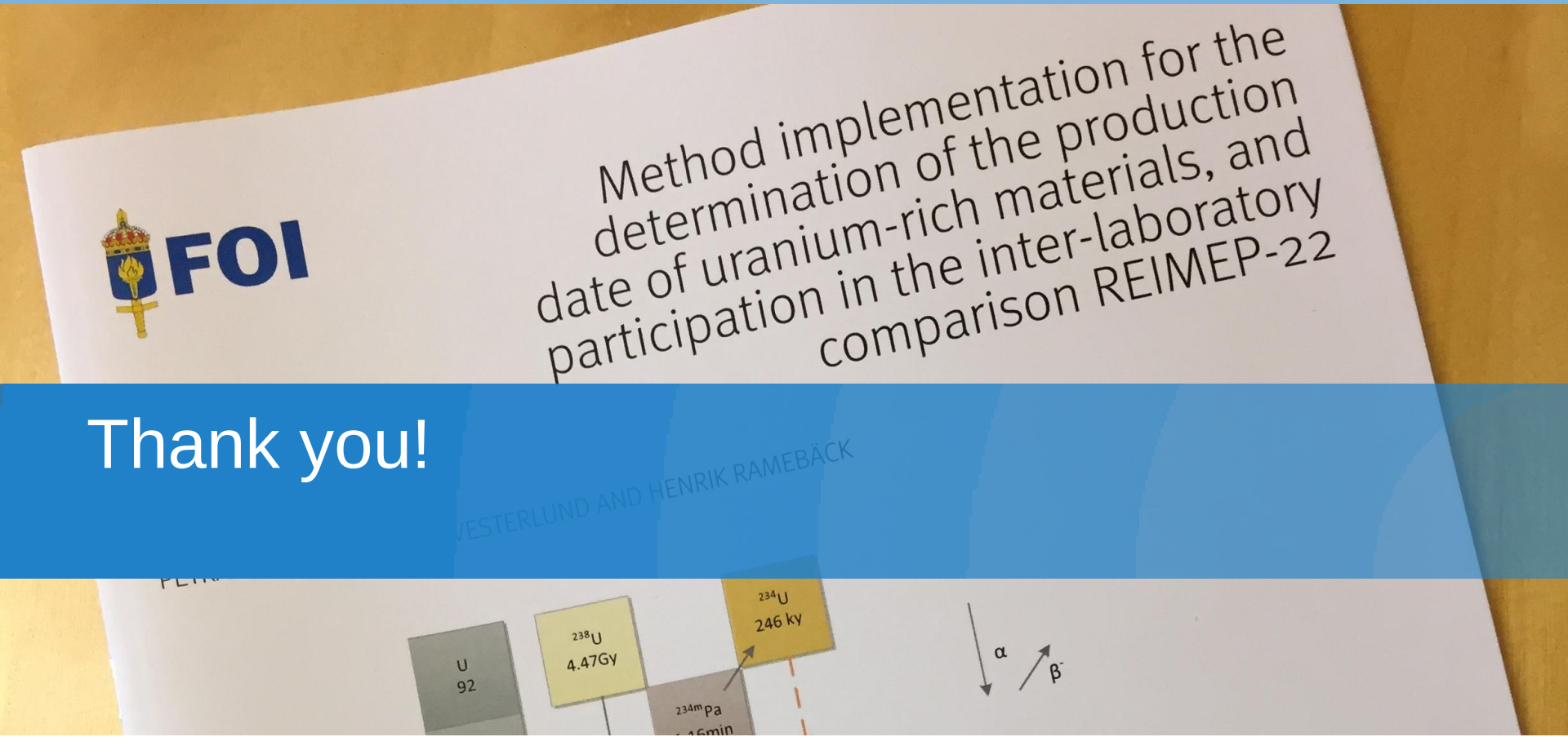
Conclusions

- Chemical yield about 40%
- Matrix for measurement not optimal
- Clean room environment not necessary

- Still, happy with the results!

Thank you!


Method implementation for the determination of the production date of uranium-rich materials, and participation in the inter-laboratory comparison REIMEP-22
U
92
238U
4.47Gy
234mPa
234U
246 ky
α
β-